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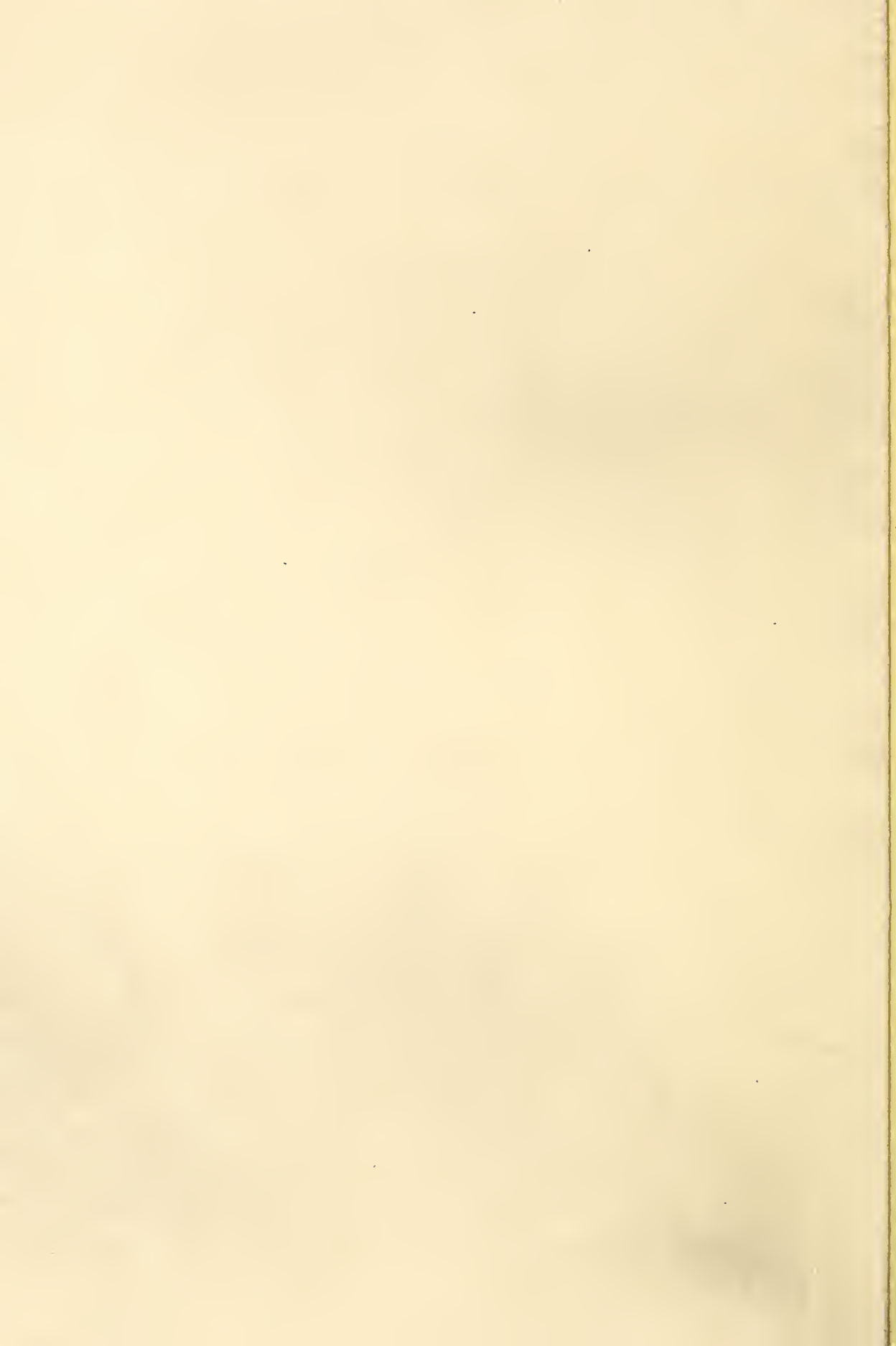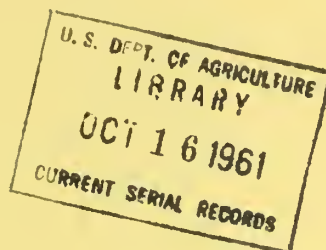
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August 1961

How to Use the

2-INDEX SYSTEM

for rating

Forest Fire Danger

by A.W. Lindenmuth, Jr.

Forest Service, U. S. Department of Agriculture

Rocky Mountain Forest & Range Experiment Station,

Fort Collins, Colorado   Raymond Price, Director

F O R E W O R D

Fire danger rating is not static: it is a fluid concept and operation molded by sustained research in forest fuels, forest fire behavior, forest fire meteorology, forest fire chemistry, forest fire physics, forest fire control operations, and other categories. Revisions and amendments to this handbook will be prepared as needed by forest fire control organizations to maintain an up-to-date fire danger rating system.

The 2-index system was deliberately designed to permit easy assimilation of improvements.

RAYMOND PRICE, Director

HOW TO USE THE 2-INDEX SYSTEM FOR

RATING FOREST FIRE DANGER

by

A. W. Lindenmuth, Jr., Forester

Rocky Mountain Forest and Range Experiment Station[1]
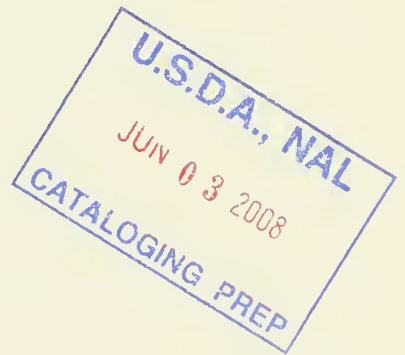
1/ The station maintains central headquarters at Fort Collins, Colorado, in cooperation with Colorado State University. Part of the information contained herein was developed while the author was employed by the Southwest Region of the U. S. Forest Service.

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HOW TO USE THE 2-INDEX SYSTEM FOR

RATING FOREST FIRE DANGER

by

A. W. Lindenmuth, Jr.

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The principles followed in developing the 2-index system for rating forest fire danger in the ponderosa pine type of the Southwest have been published. [2] This is a discussion of how to calculate, record, interpret, and apply the two indexes, and how to sample fire weather.

The two indexes of this system are a drought index and a rate-of-spread index, which are calculated and interpreted separately.

The drought index is calculated from (1) precipitation for the preceding winter, (2) season of year, (3) fire-season precipitation, and (4) daily air temperatures. Calculations start in the spring. Thereafter, drought index accumulates from day to day during precipitation-free periods by amounts that depend upon precipitation for the preceding winter, season of year, and daily air temperature. The amount of daily accumulation is determined from 1 of 15 tables, 1 for each combination of 3 levels of preceding winter precipitation and 5 different seasons of year. Within each table, the rate of accumulation of drought index depends only upon daily air temperature.

Precipitation reduces drought index. The amount of reduction depends upon the amount of current precipitation, amount of precipitation for the preceding winter, and the level of drought index before the rain. Adjustments for any combination of existing drought index and nine levels of current precipitation are obtained from one of three tables; one for each of three levels of preceding winter's precipitation.

Rate-of-spread index is based upon a litter-moisture factor, daily air temperature, and daily wind velocity. Litter-moisture factor, in turn, is determined from precipitation, daily air temperatures, and time since last rain.

CALCULATING THE TWO INDEXES

DROUGHT INDEX

Drought-index calculations start in spring when the winter's snow melts or, in the event of an open winter, when average daily temperatures regularly reach 50° F. or more. The decision to begin calculating is based on conditions in timbered areas large enough that the drying of dead fuels would create a fire hazard.

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[2] Lindenmuth, A. W., Jr. Development of the 2-index system of rating forest fire danger. Jour. Forestry 59: 504-509, illus. 1961.

Although guides for setting the starting date cannot be expressed precisely, that is not serious because the effect of small differences in starting date disappears before drought index reaches a serious level.

Snow melt should be used as the guide whenever possible. Calculations start when all but a few scattered snow banks have melted, the snow water has run off, and litter from snow-free areas has dried to the point that water will not run out of a sample when squeezed in the hand.

The rule is to base the starting date on lands that begin drying earliest in spring and also occupy a large enough part of the protection unit to constitute a fire hazard. Southerly aspects normally start drying first. If a protection unit has a significant portion of southerly aspects, the starting date should be based on these southerly aspects. If the earliest drying area is flat, and it makes up a significant part of the unit, the starting date should be based on flats.

A temperature guide is used in warmer climates, or in normally snowy climates following open winters. Calculations start when average temperature, which is the sum of the 24-hour maximum and minimum divided by 2, regularly rises to 50°F. or above. The temperature guide is determined by looking back over the record for at least 10 days.

In the example shown in table 1 it would be proper to start drought-index calculations at the beginning of the first 10-day period having a 10-day average temperature of 50° F., or February 1, provided it is the time of year when the 10-day average temperature probably will remain at, above, or near 50° F.

Table 1.--An example of procedure for using average temperature as the guide for starting drought-index calculations

Date		Sum of maximum and minimum temperatures	Daily average temperature[1]	10-day average temperature
		Degrees Fahrenheit		
Jan.	30	86	43	--
	31	75	38	--
Feb.	1	98	49	--
	2	86	43	--
	3	114	57	--
	4	93	46	--
	5	98	49	--
	6	98	49	--
	7	99	50	--
	8	102	51	--
	9	108	54	49
	10	104	52	50
	11	105	52	50
	12	106	53	51
	13	98	49	50
	14	105	52	51
	15	109	54	52

[1] Preceding daily temperatures averaged less than 50° F.

After the starting date has been determined, calculations are brought up to date on the basis of the temperature record, which must be kept daily when there is likelihood of getting average temperatures of 50° F. or more. Nothing important is lost by delaying the start of drought-index calculations for 10 days. The index will not rise high enough during beginning of the season to be important.

Winter Precipitation

The rate at which drought index accumulates depends in part on total precipitation for the preceding winter. The next step therefore is to calculate winter precipitation, which is the total amount for the period from the discontinuance of drought-index calculations in autumn until calculations start again in spring. Calculations stop in November or December with the first snowfall that lingers or with the first general precipitating storm after December 1 that is followed by average daily temperatures below 50° F.

Total winter precipitation is divided into three classes: (1) 2.50 inches and less, (2) 2.51 - 3.50 inches, and (3) 3.51 inches and more. A separate set of drought-index tables is provided for each class. The same set is used during the entire year. Only the correct set should be available at each fire danger station each year so there will be no chance for the observer to use the wrong set.

Season of the Year

Separate tables are provided for each of five seasons. Seasons are: (1) November 1 - February 28, (2) March 1 - April 15, and October 16-31, (3) April 16-30 and September 1 - October 15, (4) May 1 - June 15 and July 16 - August 31, and (5) June 16 - July 15. The tables for the current date must be used. On the recommended record form at the beginning and middle of each sheet, observers are reminded to check the date in the upper right-hand corner of the tables to assure that the correct one will be used (fig. 1).

Calendar date is not considered in adjusting drought index for precipitation. There is only one table for that purpose for any one year. It is suitable for all dates.

Now you are ready to compute daily drought index.

Today's Calculations

No rain preceding 48 hours. --If no precipitation was measured today at 1:00 p.m. and none was measured yesterday, use the table for the current season labeled "no rain preceding 48 hours." Read today's drought index from the line representing yesterday's index and the column representing the temperature for today (table 2). On the day calculations are started in spring, yesterday's index is assumed to be zero.

FIRE DANGER STATION RECORD

Winter Precipitation **2.50** inches

(Make 1 carbon copy and send to **Supervisor** monthly.)

Forest **Mona**
District **Red Creek**
Station **Alpena**
Month **July** Year **1961**

Date	1:00 P.M. MEASUREMENTS				CALCULATIONS **140** **72**			FORECASTS[3] (**Jonesboro, N.M.**)				
	Lightning[1]	Precipitation[1]	Temperature[2]	Wind	Fuel Moisture Factor	Drought Index	Rate of Spread Index	Temperature	Wind	Lightning	Drought Index	Rate of Spread Index
CHECK DATE USED IN ALL CALCULATIONS												
1	0		75	10	15.0	74	20	76	5-10	0	74	20
2	0		78	12	16.0	76	25	77	10-15	0	76	30
3	0		69	20	17.0	78	45	70	15-20	0	78	45
4	0		72	5	18.0	80	25	73	5-10	0	80	25
5	0		76	9	19.0	82	30	75	5-10	0	82	30
6	L		77	20	20.0	84	55	80	15-20	L	84	60
7	L	.10	65	15	0.5	84	10	68	5-10	L	86	30
8	0		75	5	1.5	84	5	75	5-10	0	84	5
9	0		79	7	2.5	86	5	80	5-10	0	86	5
10								70	10-15	0	88	10
11												
12												
13												
14												
15												
CHECK DATE USED IN ALL CALCULATIONS												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

[1]. 24 hour period ending 1:00 P.M. today.
[2]. Maximum temperature for the day may be substituted.
[3]. Give name of originating office.

1126-R3
(April 1957)

Figure 1. --Sample fire danger station record.

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Table 2. --Sample table for calculating drought index when no precipitation has been measured during the preceding 48 hours

DROUGHT INDEX TABLE

Winter Precipitation 2.50 in. or less

Revised   January 1959

Period   June 16-30 / July 1-15

Yesterday's Index 1/	Today's Index — No Rain Preceding 48 Hours — Maximum Temperature						Yesterday's Index 1/	Today's Index — No Rain Preceding 48 Hours — Maximum Temperature					
	80 minus	81 85	86 90	91 95	96 100	101 plus		80 minus	81 85	86 90	91 95	96 100	101 plus
0	53	53	54	56	57	58	93	93.0	93.0	93.0	93.0	94	94
45	53	54	55	56	57	58	93.0	93.1	93.1	93.1	93.1	94	94
46	53	54	55	56	57	58	93.1	94.0	94.0	94.0	94.0	94	94
47	54	54	55	56	57	59	94	94.0	94.0	94.0	94.0	94.0	94.0
48	54	55	56	57	58	59	94.0	94.1	94.1	94.1	94.1	94.1	94.1
49	55	55	57	58	58	59	94.1	94.2	95.0	95.0	95.0	95.0	95.0
50	56	56	57	58	59	60	94.2	95.0	95.0	95.0	95.0	95.0	95.0
51	56	57	58	59	60	61	94.0	95.1	95.1	95.1	95.1	95.1	95.1
52	57	57	58	59	60	61	95.1	95.2	95.2	96.0	96.0	96.0	96.0
53	58	58	59	60	61	62	95.2	96.0	96.0	96.0	96.0	96.0	96.0
54	58	59	60	61	62	63	96.0	96.1	96.1	96.1	96.1	96.1	96.1
55	59	60	61	62	62	63	96.1	96.2	96.2	96.2	97.0	97.0	97.0
56	60	61	62	62	63	64	96.2	96.3	96.3	96.3	97.0	97.0	97.0
57	61	61	62	63	64	64	96.3	97.0	97.0	97.0	97.0	97.0	97.0
58	62	62	63	64	64	65	97.0	97.1	97.1	97.1	97.1	97.1	97.1
59	63	63	64	64	65	66	97.1	97.2	97.2	97.2	97.2	97.2	97.2
60	63	64	64	65	66	67	97.2	97.3	97.3	97.3	97.3	97.3	98.0
61	64	65	65	66	66	67	97.3	97.4	97.4	97.4	97.4	98.0	98.0
62	65	65	66	67	67	68	97.4	97.5	97.5	98.0	98.0	98.0	98.0
63	66	66	67	68	68	69	97.5	97.6	98.0	98.0	98.0	98.0	98.0
64	67	67	68	68	69	70	97.6	98.0	98.0	98.0	98.0	98.0	98.0
65	68	68	69	69	70	71	98.0	98.1	98.1	98.1	98.1	98.1	98.1
66	69	69	70	70	71	72	98.1	98.2	98.2	98.2	98.2	98.2	98.2
67	70	70	71	71	72	73	98.2	98.3	98.3	98.3	98.3	98.3	98.3
68	71	71	72	72	73	74	98.3	98.4	98.4	98.4	98.4	98.4	99.0
69	72	72	73	73	74	74	98.4	98.5	98.5	98.5	98.5	99.0	99.0
70	73	73	74	74	75	75	98.5	98.6	98.6	98.6	99.0	99.0	99.0
71	74	74	74	75	75	76	98.6	98.7	98.7	99.0	99.0	99.0	99.0
72	74	75	75	76	76	78	98.7	98.8	99.0	99.0	99.0	99.0	99.0
73	75	76	76	77	77	78	98.8	99.0	99.0	99.0	99.0	99.0	99.0
74	76	77	77	77	78	78	99.0	99.1	99.1	99.1	99.1	99.1	99.1
75	77	77	78	78	79	79	99.1	99.2	99.2	99.2	99.2	99.2	99.2
76	78	78	79	79	80	80	99.2	99.3	99.3	99.3	99.3	99.3	99.3
77	79	79	80	80	81	81	99.3	99.4	99.4	99.4	99.4	99.4	99.4
78	80	80	81	81	81	82	99.4	99.5	99.5	99.5	99.5	99.5	100
79	81	81	82	82	82	83	99.5	99.6	99.6	99.6	99.6	100	100
80	82	82	82	83	84	84	99.6	99.7	99.7	99.7	100	100	100
81	83	83	83	84	84	85	99.7	99.8	99.8	100	100	100	100
82	84	84	84	85	85	86	99.8	99.9	100	100	100	100	100
83	85	85	85	86	86	87	99.9	99.10	100	100	100	100	100
84	86	86	86	87	87	88	99.10	100	100	100	100	100	100
85	87	87	87	88	88	88							
86	88	88	88	88	89	89							
87	88	89	89	89	89	90							
88	89	89	89	90	90	90							
89	90	90	90	91	91	91	No further change						
90	91	91	91	91	92	92							
91	91.0	92	92	92	92	92							
91.0	91.1	92	92	92	92	92							
91.1	92.0	92	92	92	92	92							
92	92.0	92.0	92.0	93	93	93							
92.0	92.1	92.1	92.1	93	93	93							
92.1	93.0	93.0	93.0	93.	93	93							

1/ or index on last day before several successive days with measurable precipitation.

The higher drought indexes carry extra digits, like 89.0 or 92.11 (may also be written 89/0 or 92/11). The extra digits are not decimals; they show how many days have passed since the last increase in the index. On the tail end of the drying curve, daily losses of moisture are not large enough to justify increasing drought index a whole number every day. Sometimes the index remains the same for as many as 17 days before coarse fuel loses enough moisture to justify increasing drought index one whole point. The extra digits are simply a device for keeping track of time that has passed since the last whole digit increase in drought index.

If yesterday's index was a round number as 89 but 89 is not listed in yesterday's index column of the table, 89.0 will be found and is used in place of 89. A round number automatically assumes a zero behind the decimal when the round number does not appear in yesterday's index column.

No rain preceding 24 hours, but rain within preceding 48 hours. --If no precipitation is measured at 1:00 p.m. today, but precipitation was measured at 1:00 p.m. yesterday, today's index is exactly the same as yesterday's index.

Rain during preceding 24 hours. --When precipitation is measured at 1:00 p.m. today the index is reduced in proportion to the amount of precipitation (water equivalent) measured. This is done with the recharge table labeled "Rain during preceding 24 hours" (table 3).

Read today's drought index from the line representing yesterday's index and the column representing the amount of precipitation measured.

If yesterday's index carried an extra digit, such as 95.7, do not drop the extra digit but disregard it in getting the change, if any, from yesterday's to today's index. Locate 95 in yesterday's index column. Then move horizontally to the proper precipitation column. If the number listed there is 93, add the extra digit to it. Today's index then becomes 93.7 and is recorded that way.

If yesterday's index was 95.7 and today's index is listed as 95, it automatically is recorded as 95.7. There is no change from the day before.

Unless the extra digit is carried along, the reduction made for precipitation is too large. When the index is 95.7, it means that drought index has been 95 for 8 days. Hence, if the index is dropped back to 93 without the suffix "7," it means that the reduction is equivalent to 8 days plus the number of days required to advance from 93 to 95. In the event today's index thus obtained has an extra digit larger than that shown in the proper drying table, for example if today's index becomes 93.7 but 93.5 is the largest index shown in the proper drying table, raise today's index to the next round number: in this instance, to 94.

If the precipitation was snow, drought index is not increased again until the second 24-hour period after the snow has melted, the water has run off, and a sample of litter will not drip water when squeezed in the hand. That is true even if snow lies for several days before it melts. The amount of precipitation recorded should be followed by the suffix "S" on the record form when this procedure is followed.

Table 3. --Sample table for reducing drought index after precipitation

Winter Precipitation 2.50 in. or less

DROUGHT INDEX

Yesterday's Index	Today's Index 1/ — Rain during preceding 24 hours								
	T .20	.21 .40	.41 .80	.81 1.20	1.21 1.60	1.61 2.10	2.11 2.60	2.61 3.10	3.11 plus
45	45	-	-	-	-	-	-	-	-
46	46	-	-	-	-	-	-	-	-
47	47	45	-	-	-	-	-	-	-
48	48	46	-	-	-	-	-	-	-
49	49	47	-	-	-	-	-	-	-
50	50	48	-	-	-	-	-	-	-
51	51	49	45	-	-	-	-	-	-
52	52	50	46	-	-	-	-	-	-
53	53	51	47	-	-	-	-	-	-
54	54	52	48	-	-	-	-	-	-
55	55	53	49	-	-	-	-	-	-
56	56	54	50	-	-	-	-	-	-
57	57	55	51	45	-	-	-	-	-
58	58	56	52	46	-	-	-	-	-
59	59	57	53	47	-	-	-	-	-
60	60	58	54	48	-	-	-	-	-
61	61	59	55	49	-	-	-	-	-
62	62	60	56	50	-	-	-	-	-
63	63	61	57	51	-	-	-	-	-
64	64	62	58	52	-	-	-	-	-
65	65	63	59	53	-	-	-	-	-
66	66	64	60	54	45	-	-	-	-
67	67	65	61	55	46	-	-	-	-
68	68	66	62	56	47	-	-	-	-
69	69	67	63	57	48	-	-	-	-
70	70	68	64	58	49	-	-	-	-
71	71	69	65	59	50	-	-	-	-
72	72	70	66	60	51	-	-	-	-
73	73	71	67	61	52	45	-	-	-
74	74	72	68	62	53	45	-	-	-
75	75	73	69	63	54	45	-	-	-
76	76	74	70	64	55	45	-	-	-
77	77	75	71	65	56	46	45	-	-
78	78	76	72	66	57	47	45	-	-
79	79	77	73	67	58	48	45	-	-
80	80	78	74	68	59	49	45	-	-
81	81	79	75	69	60	50	45	-	-
82	82	80	76	70	61	51	45	-	-
83	83	81	77	71	62	52	46	45	-
84	84	82	78	72	63	53	47	45	-
85	85	83	79	73	64	54	48	45	-
86	86	84	80	74	65	55	49	45	-
87	87	85	81	75	66	56	50	45	-
88	88	86	82	76	67	57	51	46	45
89	89	87	83	77	68	58	52	47	45
90	90	88	84	78	69	59	53	48	45
91	91	89	85	79	70	60	54	49	45
92	92	90	86	80	71	61	55	50	45
93	93	91	87	81	72	62	56	51	45
94	94	92	88	82	73	63	57	52	45
95	95	93	89	83	74	64	58	53	45
96	96	94	90	84	75	65	59	54	45
97	97	95	91	85	76	66	60	55	45
98	98	96	92	86	77	67	61	56	45
99	99	97	93	87	78	68	62	57	45
100	100	98	94	88	79	68	62	53	45

1/ Today's Index never drops below 45. If rain is measured on several successive days, use the sum of the precipitation for the preceding days in calculating Today's Index.

<u>Rain on two or more successive days.</u> --If precipitation is measured at 1:00 p.m. on two or more successive days, the drought index on the last day before the rain is used as yesterday's index and the sum of the rain measured on the successive days is used as "Rain during preceding 24 hours." Today's index is then determined in the usual way.

Tomorrow's Calculations

Tomorrow's index is always based on the index for today. The only additional information needed is a forecast of tomorrow's temperature. Fire-weather forecasts and also regular local weather forecasts are generally reliable for temperature. In looking up the index for tomorrow the "yesterday" and "today" columns in the table are interpreted as applying to today and tomorrow respectively.

RATE-OF-SPREAD INDEX

Rate-of-spread indexes are not cumulated.

Calculations for rate-of-spread index therefore do not have to start in spring at the same time as calculations for drought index. While drought index is low, fires will not be serious and fire prevention and preparedness plans may remain static irrespective of current changes in weather. In that event there is no purpose in calculating rate-of-spread indexes; the start of calculations may be delayed until rate-of-spread indexes are needed.

The choice of starting date will depend on fire plans for the unit. If the organization and activities are changed as current weather changes within the moderate drought index class, rate-of-spread calculations must start by the time drought index reaches moderate. If rate-of-spread index does not alter plans until drought index goes higher, the start of calculations can be postponed until drought index reaches the higher level. In any event, specific instructions for starting rate-of-spread calculations should be part of fire plans.

Rate-of-spread index is based on three factors.

Litter-moisture Factor

Litter-moisture factor represents the moisture content of litter (needles, branchlets, etc.) but is not the same as an actual measurement of moisture in litter. It increases daily during rain-free periods at a rate that depends on daily air temperatures. It is reduced by precipitation.

Litter-moisture factor is cumulative. Calculations start immediately after a known amount of precipitation at any time and must be continuous thereafter.

On days when precipitation is measured at 1:00 p.m., litter-moisture factor for today is read directly from the following tabulation, which is also found on the envelope type slide rule furnished for calculating litter-moisture factor (fig. 2).

Amount of precipitation	Litter-moisture factor
(inches)	
Trace (less than 0.005)	1.8
0.005 - 0.05	1.0
0.06 plus	0.5

RATE OF SPREAD METER INSTRUCTIONS

1. Calculate Litter Moisture Factor (to one decimal) with LMF Adjuster.

2. On the ROS Meter, set the calculated LMF value (to one decimal) opposite the arrow on the center tab.

3. Next, set the value (nearest degree) for temperature opposite the arrow on the LMF disc. Temperature is the value read at 1:00 P.M. today or the maximum for today.

4. Then, set the value (nearest 1/2 mile) for wind velocity opposite the arrow on the temperature disc.

5. Finally, read Rate-of-Spread Index in the segment opposite the arrow on the wind disc.

LITTER MOISTURE FACTOR ADJUSTER

Precipitation during preceding 24 hours.		No precipitation preceding 24 hours.		Instructions
AMOUNT (inches)	LM FACTOR	DATE	SEPT. OCTOBER (1-15) APRIL (16-30)	1. Start LMF calculations during a 24 hr. period with precipitation.
Troce	1.8			2. In 24 hr. periods with precipitation LMF is read directly from table at far left.
T-0.05	1.0			
0.06 plus	0.5			

TODAY'S TEMP.	ADD
65-	0.3
66-70	0.4
71-75	0.5
76-85	0.6
86⊬	0.7

(Amount of precipitation is the amount measured during one or more consecutive 24 hour periods of precipitation.)

3. In 24 hr. periods without precipitation LMF is calculated by reading the proper amount to add in the lower window and adding it to the LMF for yesterday.

Figure 2.--Picture of slide rule for calculating litter-moisture factor, also instructions for operating rate-of-spread meter.

This tabulation is always used when there is precipitation because the factor always drops back to one of the three values given. If precipitation is measured on two or more successive days, the precipitation measurements

are added and the total is used to determine the factor for today. But in the event the factor was 0.5 yesterday and 0.005 to 0.05 inch of precipitation is measured today, the factor is not increased to 1.0 for today. Litter-moisture factor is always held at the lowest value until a 24-hour period without precipitation, then it is increased.

"Trace" refers to a quantity of precipitation that is less than 0.005 inch (less than half the distance to the first mark on the lower end of the measuring stick), but sufficient to wet the tip of the measuring stick at 1:00 p.m. If precipitation was not sufficient to wet the tip of the stick at 1:00 p.m. it will have no influence on litter-moisture factor.

If this definition of "measurable trace at 1:00 p.m." conflicts with the definition of trace for records that will be submitted to the U. S. Weather Bureau or other agency, do not change the records. Instead, change the litter-moisture factor table to read "less than 0.005 inch" instead of "trace."

The data required to calculate litter-moisture factor are always available when drought index is being calculated. If you decide to start rate-of-spread calculations on May 1, for example, and the last rain was April 20, it is no problem to go back to April 20 and bring litter-moisture factor calculations up to May 1--temperatures and precipitation for doing so are already recorded.

After calculations are started, the factor is increased every day (when there is no precipitation) by an amount read in the lower window of the slide rule after the slide has been set for the correct date, which appears in the upper window. The amount read opposite the temperature for today is added to the factor for yesterday to get the factor for today (see fig. 1). This procedure is repeated daily until the factor reaches 20.0. It stays at 20.0 until precipitation is measured.

Operating the Rate-of-Spread Meter

The following instructions for operating the rate-of-spread meter (fig. 3) are applicable on all days except when the unit is covered with enough snow to prevent spread of fire. Rate-of-spread index is automatically zero when, and only when, the rating unit is blanketed with snow.

1.   Set the value for litter-moisture factor opposite the arrow on the center tab (interpolate on the scale for fractional values).

2.   Set the temperature reading for today opposite the arrow on the outer edge of the litter-moisture factor disc (interpolate on the scale for individual degrees).

3.   Set the wind velocity reading for today opposite the arrow on the outer edge of the temperature disc (interpolate on the scale for fractional values).

4.   Read rate-of-spread index in the segment opposite the arrow on the outer edge of the wind disc (do not interpolate for fractional values within the segment; record the index as 5, 10, 15, etc.).
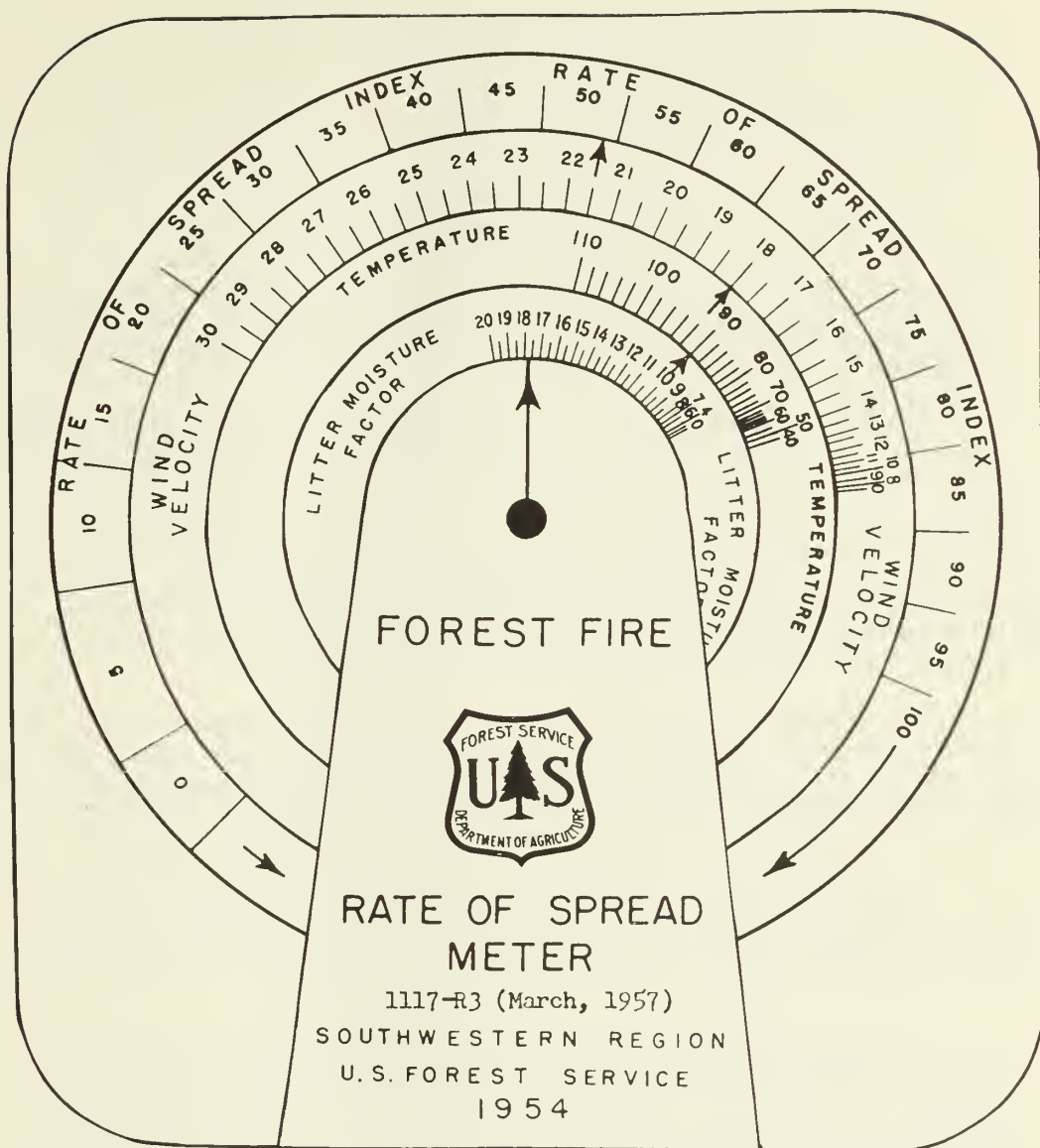
Figure 3. --Picture of rate-of-spread meter.

Tomorrow's Calculations

As in drought index, calculation of tomorrow's litter-moisture factor is based on the value of the factor today and the increase that will accompany the forecast of temperature for tomorrow. Then tomorrow's estimated factor, predicted temperature, and predicted wind velocity are set up on the meter to find estimated rate-of-spread index for tomorrow.

RECORDING THE TWO INDEXES

Measurements made to rate fire danger for the day, and only these, should be recorded on the standard form (see fig. 1). Other measurements, such as those made to estimate the rate at which a particular going fire probably will spread, for example, may be made at any time, but it is better

not to record such extra, optional measurements on the station record. Extra measurements are made for specific purposes and they serve their purpose best if recorded in the log for the particular fire or similar suitable place.

The record form is divided into three sections: (1) measurements, (2) calculations, and (3) forecasts. Daily measurements of precipitation, temperature, and wind are recorded in their respective columns. An observation of lightning completes the measurements section. When there have been lightning strikes in the station territory during the 24-hour period ending at 1:00 p.m. today, record the intensity of the storm, H for high intensity, M for moderate intensity, and L for low intensity. Otherwise record a zero or checkmark indicating that there was no lightning and the observation was not overlooked.

The lightning classes cannot be defined objectively; they are based on impressions rather than measurements. High intensity refers to many and "hot" bolts of lightning. Light intensity refers to scattered bolts. Moderate intensity refers to conditions in between. Although this lightning classification is more intuitive than objective, it has value as a record of when lightning occurs and to some degree the risk each storm presents. This information can be used in improving fire plans and possibly in improving fire-danger rating. This information has been recorded with reasonable uniformity in the Southwest since 1955.

Calculated daily values for litter-moisture factor (called fuel-moisture factor on the form), drought index, and rate-of-spread are recorded in the calculations section. At the end of a month, litter-moisture and drought-index values for the last day are carried forward to the form for the next month. The values are recorded at the top of their respective columns.

The forecast section is the place for predictions of lightning, temperature, and wind, and for estimating indexes. At the top of this section the name of the weather forecasting office may be inserted for reference if comparisons are to be made between forecast and actual values.

Forecasted values are those received, calculated, or estimated sometime prior to the start of the burning period for today, 10:00 a.m. On the morning of the 10th of the month (see fig. 1), the forecast values for the 10th have been recorded on the record sheet along with a complete record in all columns for the preceding 9 days. The fire-control organization for the morning of the 10th should be set up on the basis of the forecast. As the day progresses, changes can and should be made if it is found that actual conditions are developing differently than expected.

Estimated drought index and rate-of-spread index for tomorrow are based on: (1) today's litter-moisture factor and drought index, which are known values, and (2) forecasts of temperature and wind for tomorrow. Errors in estimated rate-of-spread and drought indexes are not cumulative. Estimated drought index on days without precipitation should always be within just one or two points of actual. Estimated rate-of-spread index should be in the correct planning class practically every day if estimates are thoughtfully made.

The fire danger station record should be posted currently, accurately, and clearly. The record has lasting value.

The two indexes have both individual and complementary significance; in operation they go together just like bread and butter. Individual significance will be discussed first; paired significance will be discussed later.

DROUGHT INDEX

Drought index is an estimate at a specific time of the average moisture content of coarse fuel--logs, large branches, stumps, and similar dead material--in a fire protection unit. Drought-index curves (fig. 4), which present the same data as drought-index tables are simply coarse fuel drying and recharge curves turned upside down; high drought index is equivalent to low moisture content and vice versa.
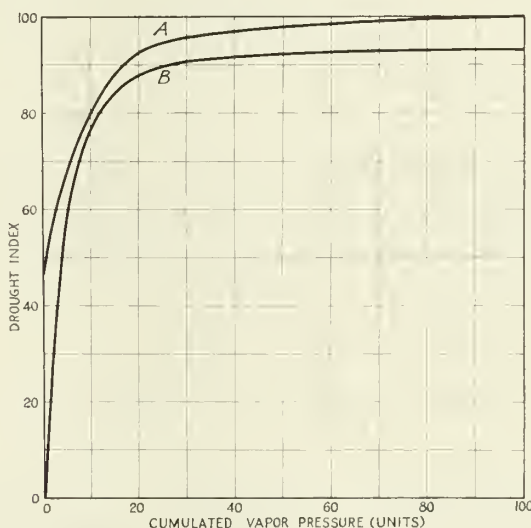
Figure 4. --Drought index curves are the same as drying and recharge curves turned upside down. Curve A is for a season following low wintertime precipitation; and curve B, for a season following high wintertime precipitation. The intermediate curve used in the 2-index system is not shown.

Moisture content largely controls how much of the total amount of coarse fuel is readily available for combustion. Thus, moisture content controls how much energy will be released when coarse fuel burns. When drought index is low, which means that coarse fuels are relatively wet, only a small part, if any, of the coarse fuel will burn. Little net energy will be released from coarse fuel, hence fires have little potential to become serious.

To facilitate interpretation and use, indexes have been divided into classes; (1) low, 0 - 56 inclusive, (2) moderate, 57 - 76 inclusive, (3) high, 77 - 90 inclusive, and (4) extreme, 91 - 100 inclusive. The division points

correspond with significant changes in slope on the curves. The average characteristics of coarse fuel for each class follows:

Low Class

Coarse fuel is wet and the moisture is chiefly free water. Generally the outer layers of coarse fuel are too wet to ignite and burn.

Moderate Class

This is an intermediate or transition class. Coarse fuel generally is still moist. But free water in the coarse fuel is just about all evaporated and surface layers are drying to the point where fuel will ignite and burn readily. There is no record of a serious fire during these conditions. The potential for fires to become serious is still small.

High Class

In the high and extreme classes coarse fuel is flammable, and severe fires occur.

The circles and dots in figure 5 represent aggressive fires that either became serious or indicated by their behavior that they had the potential for becoming serious. These fires were attacked while small. The ones that did not actually become serious were held successfully by the initial attack force.
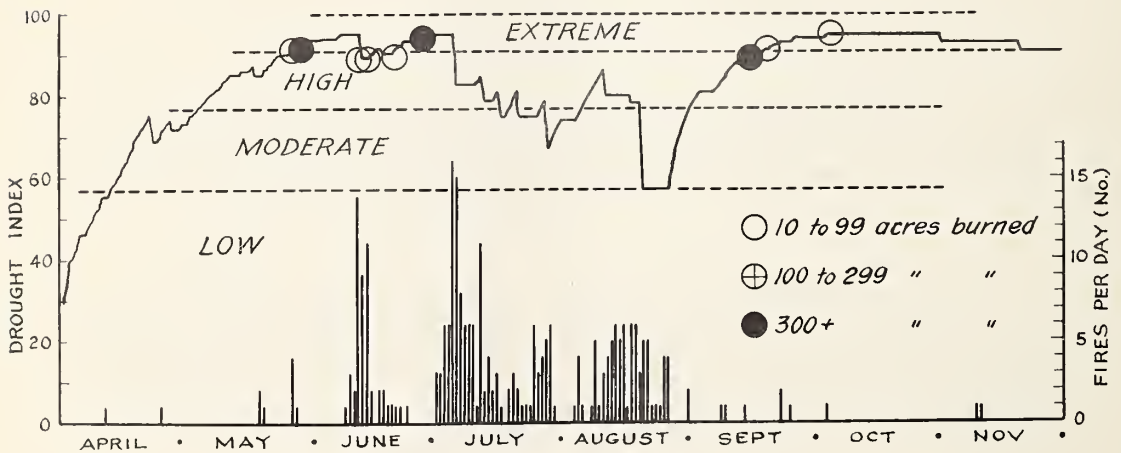
Figure 5. --Aggressive fires, shown by the circles and dots on the drought index trace, burn only when drought index is high or extreme, even though fires burn over a wide range of drought index. Gila National Forest. 1953.

The difference between the high class and the extreme class is a matter of degree. Coarse fuel is dry enough to burn in the high class but it is even drier in the extreme class.

As will be explained later, rate-of-spread index is important in interpreting drought index in both the high and extreme classes.

Extreme Class

Coarse fuel burns readily in this class, and burning releases a large portion of the total energy in the fuel as net energy. Most of the serious fires in the past have burned during extreme conditions.

Discussion

Drought index tends to build up slowly in spring (fig. 6). Vapor pressures normally cumulate slowly in spring because temperatures are relatively low. In addition, showers sometimes arrest drying or actually restore some moisture (flats and valleys in the graph during April).
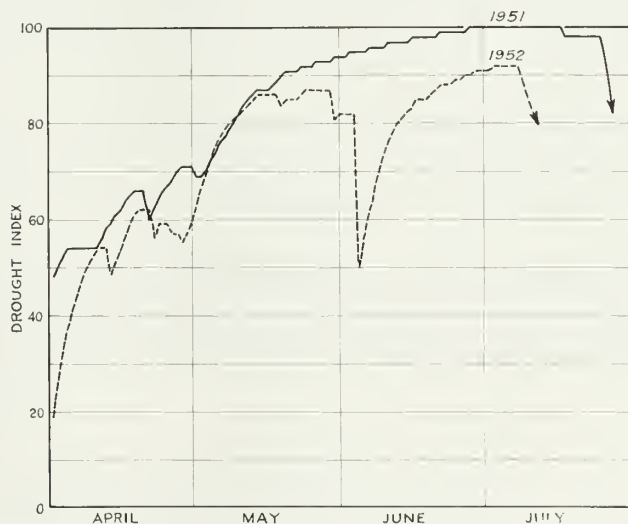
Figure 6. --Actual drought indexes for the Gila National Forest, southern New Mexico, for a bad fire season (1951) and an easy fire season (1952) show similar trends in the spring and differences after reaching the high class (77) or the beginning of the critical range for drought index.

Drought index tends to build up similarly every spring in some localities irrespective of the amount of preceding winter precipitation. This ties back to the moisture drying and recharge curves (see fig. 4). The curves are similar in the low and moderate classes because free water is chiefly involved.

The index while climbing through the low and moderate classes should not be taken as an indicator of how serious burning conditions will be later on. Indexes for bad, easy, or average seasons can all look alike at that stage.

The amount of preceding winter precipitation provides a clue for predicting the severity of the season to come. In figure 6 the 1951 season was preceded by 2.50 inches of precipitation and the 1952 season by 4.44 inches. Although records have not yet been taken long enough to determine accurately the relationship between winter precipitation and severity of fire seasons, history indicates that bad seasons tend to follow winters with small precipitation and easy or moderate seasons tend to follow winters with abundant precipitation.

The influence of winter precipitation started showing up about May 10 (see fig. 6). From then on a bad season was in the making in 1951. Drought index climbed steadily until it reached 100. Drought index increased but little after May 10 in 1952. In-season precipitation first as light showers, which leveled off drought index, and then as a heavy rain, which dropped drought index to 50, had an influence. But even without precipitation in late May and June the curve would not have climbed as high in 1952 as in 1951 because of the nature of the drying curves.

Characteristics of drought index in the high and extreme classes have the most meaning in fire control. In this range drought indexes change slowly in the absence of rain. It is possible to look ahead and predict indexes several days in advance with considerable accuracy. Weather forecasters can usually predict maximum temperatures up to 5 days in advance, and predictions of departures from normal temperatures for 30 days are now available. That is all the information needed to predict drought index in the absence of precipitation.

Drought index does not follow the same pattern in all locations in all years. A rapid buildup in spring to a peak in late June or early July is found frequently in many localities in the Southwest. A different pattern is found frequently in the Black Hills National Forest, South Dakota (fig. 7).

Fire-control men using the 2-index system are charting these patterns and finding the charts very helpful in interpreting the indexes. Charts make possible the visual association of fire problems and the two indexes.
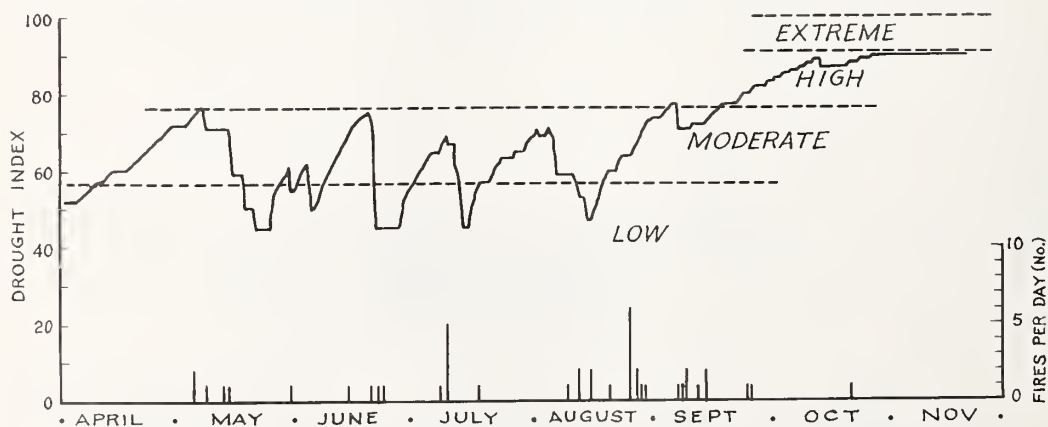

Figure 7. --Drought index in the Black Hills, South Dakota in 1952 shows the pattern created by typically wet spring and summer, and dry fall seasons.

RATE-OF-SPREAD INDEX

Rate-of-spread index is defined as an estimate at a specific time of the relative rate at which a surface fire burning litter is expected to spread along its forward axis. But for interpretative purposes rate-of-spread index is more than that. It rates the probability of fires becoming serious when they have the potential for becoming serious or extreme. Rate-of-spread index is divided into classes to facilitate interpretation and use.

Low Class

Rate-of-spread index 0 - 15 inclusive. --The level of all three variables that go into rate-of-spread index is unfavorable for ignition and combustion; moisture content of litter is relatively high, temperature is low, and wind velocity is low. Burning particles are not likely to ignite adjoining particles. Small firebrands are not likely to ignite fuels. Only lightning, debris burning, and similar large igniters commonly cause fires. Combustion proceeds at a slow rate even during the mid-day burning period. Fires usually die down or go out at other times. It is improbable that fires will become serious even if drought index is high or extreme.

Moderate Class

Rate-of-spread index 20 - 35 inclusive. --The moderate class is a transition class from low to high flammability. Wind velocity and one of the two other variables that go into rate-of-spread index are unfavorable for ignition and combustion. Ignition is easier and combustion proceeds at a faster pace than in the low class. Fires begin to show some aggressiveness. It is improbable, however, that they will become serious even when drought index is high, but they can develop into surface fires of 100 to 200 acres during the mid-day burning period if topographic and fuel characteristics encourage spread.

High Class

Rate-of-spread index 40 - 65 inclusive. --Weather conditions favor both ignition and combustion. All three variables must be well advanced or wind velocity must be 25 m.p.h. or more. If drought index is high, fires probably will become serious unless controlled promptly. Most of the potentially serious fires burn in this class. Lightning is rare but lightning-started "sleeper" fires may show up.

Extreme Class

Rate-of-spread index 70 - 100 inclusive. --Indexes in this range are rare. All three variables must be near the top of their individual ranges. Litter-moisture factor at its maximum of 20, temperature at 100, and wind velocity at 25 m.p.h. produce an index of 90, for example. Fires almost certainly will start spreading shortly after initial ignition and develop rapidly into serious fires if they have the potential for becoming serious. Runs of 20,000 acres in the first afternoon following initial ignition have been recorded when drought index was high or extreme.

Fortunately, weather that produces the extreme class is not lightning weather. Ignitions therefore are few. But of the few fires that start a high proportion become serious. The number of fires that burn when rate-of-spread index is 40 - 65 is much larger, but the proportion of serious fires is lower.

The two indexes indicate both the amount of energy that may be released by a fire and the rate at which it will be released. Together, amount and rate of energy release determines fire intensity.

Drought index indicates how much energy is readily available for release; rate-of-spread index indicates how fast it will be released.

For complete interpretation the two indexes therefore must be considered at the same time. The many combinations of the two indexes cover a wide range of intensity.

Lowest intensity is represented by combinations containing low drought index. Severe fires do not burn during such conditions irrespective of the rate-of-spread index. If rate-of-spread index is high, and fuel characteristics are especially favorable for combustion, fast running surface fires may develop, but control is relatively easy and damage is light.

Combinations that contain moderate drought index also represent relatively low intensity, but slopes, heavy concentrations of fine fuel, and other nonweather conditions may stimulate combustion enough to cause some trouble. Also, moderate drought index is transitory. Serious conditions are always just ahead unless it rains. So even though fires generally do not have a potential for becoming serious when drought index is moderate, it is unwise to allow fires to become large or to prolong control action. Fires can hang on until serious conditions arrive. Then they may break loose.

Fires generally are not difficult to control when drought index is moderate, but the suppression job does increase as rate-of-spread index increases. As a general rule, rate-of-spread index is low when drought index is moderate, and no special fire control action will be needed, but occasionally a high wind will raise rate-of-spread index to a level where special prevention and preparedness action should be taken.

When drought index is high, fires have the potential for becoming serious. Whether they will become serious and how soon after initial ignition depends on rate-of-spread index. If rate-of-spread index is low, the probability of fires becoming serious is low; a large percentage of the total fuel may be consumed but the rate at which it burns is low. The rate of energy release therefore is low, too. Thus intense spotting, fire-created whirlwinds, sustained crowning, and other characteristics of serious fires are improbable. There is no record of violent fire behavior when rate-of-spread index was low.

The same is true, in general, when rate-of-spread index is moderate, but the moderate class borders on the high class. An increase of only a few miles in wind velocity can raise rate-of-spread index from moderate to high. So although fast suppression action normally is not essential when rate-of-spread is moderate, it is unwise to let fire control action drag. A moderate rate-of-spread index should be interpreted as a get-ready signal. It means keep the deck cleared; prepare for emergencies that may arise.

When drought index is high or extreme and rate-of-spread index is also high or extreme, every fire that ignites has a good chance of becoming serious unless prevented from doing so by fast, strong suppression action. Energy is

released rapidly and the combustion process is likely to become violent when coarse fuels are dry and rate-of-spread index is 40 or above. The likelihood of violent combustion increases as either one or both of the indexes increase in the upper two classes. The fundamental objective of fire control is to eliminate violent fires by either preventing initial ignition or by control before intensity reaches the critical level.

Three illustrations of the relation between high-intensity fires and paired indexes are shown in figure 8. The fire illustrated in figure 8a ignited when drought index was high and rate-of-spread index extreme. The fire escaped from the initial attack force and burned 20,000 acres the first day. On the 4 following days, until it was controlled, the fire burned only 1,000 to 2,000 acres a day, even though the perimeter was many miles around. On three of these days rate-of-spread index was low; and on the other, moderate.

Figure 8b illustrates a high-intensity fire that started when drought index was extreme and rate-of-spread index barely high. It escaped from the initial attack force. But whereas the preceding fire burned 20,000 acres on the first day, this fire burned only 1,000 acres on the first day and made its biggest runs on the following days after rate-of-spread index became extreme. It was controlled at 19,500 acres 8 days after it started. This fire resisted control longer because drought index was extreme. It made more runs because rate-of-spread index was high or extreme on more days while the fire was out of control.

A "sleeper" that became a high-intensity fire after 9 days is illustrated in figure 8c. This fire was ignited by lightning on June 14 when both drought index and rate-of-spread index were low. It apparently smoldered until drought index reached high on June 22. A small smoke showed briefly that afternoon, but rate-of-spread index was still low. The smoke reappeared the following day at 1:26 p.m. when rate-of-spread index had reached high. The initial attack unit reached the fire at 2:30 p.m. when its size was estimated to be 200 acres. The fire escaped from the initial attack unit and became a project fire. It devastated 455 acres before it was controlled at 9:00 p.m. on June 23.

APPLYING THE TWO INDEXES

The general idea in fire control is to oppose force with force (or energy with energy). The objective is to regulate forces of fire control to the force of fires.

Fire prevention and presuppression plans deal with potential force of expected fires. Fire dispatching and fire suppression plans deal with actual force of going fires. Therefore the approach to making each type of plan is somewhat different. Fire-danger rating is used in both types of planning, but this discussion is limited to prevention and presuppression planning.

The first step in fire prevention and presuppression planning is to identify "fire seasons" (fig. 9).

Number of fires differ with season. The two indexes cannot indicate the number of fires that will ignite. About 83 percent of the fires are started by lightning and lightning is a seasonal phenomenon. It has little relation to fire-danger indexes.
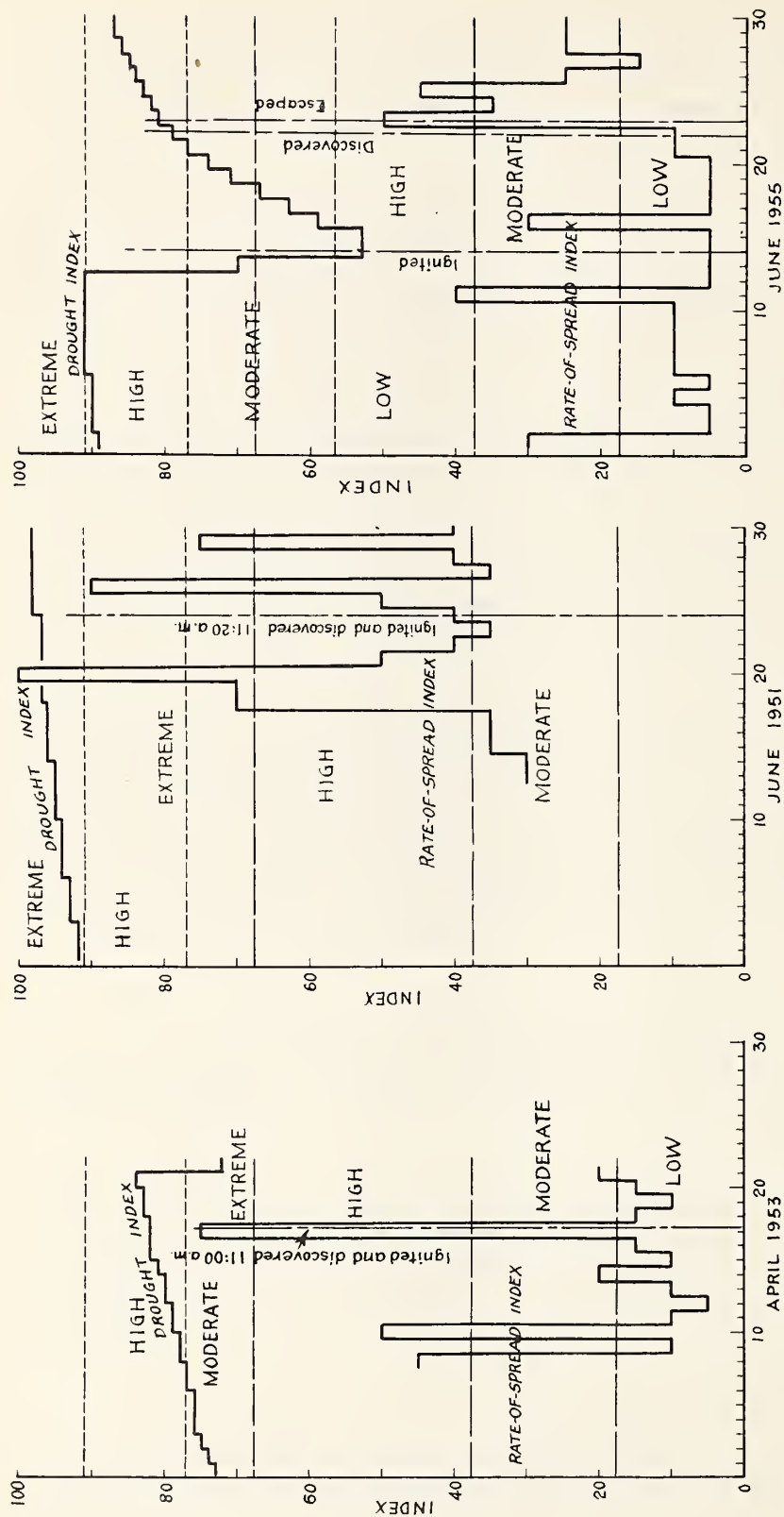
Figure 8.--

A, A high-intensity fire that burned 20,000 acres the first day when drought index was high and rate-of-spread index was extreme, but only 1,000 to 2,000 acres a day on the four following days when rate-of-spread index was only low or moderate.

B, A high-intensity fire that burned only 1,000 acres the first day when drought index was extreme but rate-of-spread index was barely high. The fire made several larger runs on the following days when rate-of-spread index was extreme.

C, A "sleeper" that ignited June 14 when both indexes were moderate or low became a high-intensity fire on June 23 when both indexes were high.
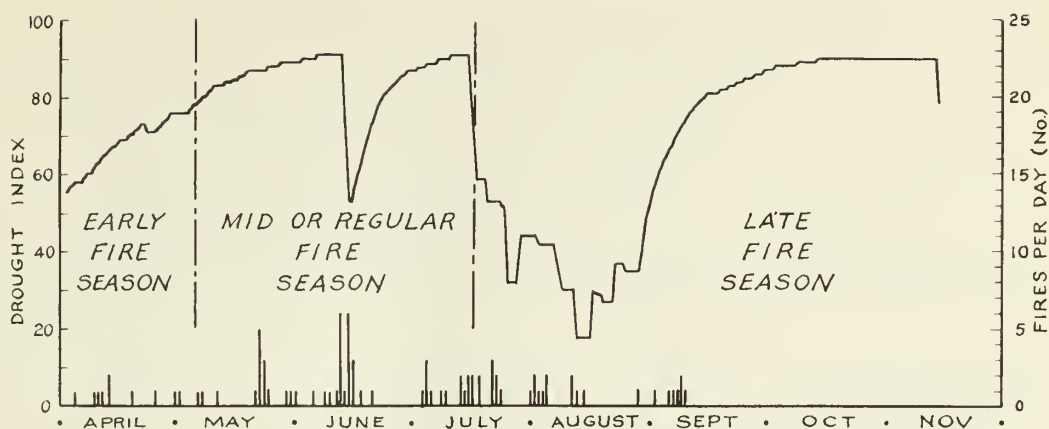
Figure 9. --The drought index trace and fire occurrence graph indicate a heavy
   fire control workload from early May to mid-July. The vertical broken lines
   divide the year into three "fire seasons" with different fire control loads.
   Coconino National Forest, Knob Hill Fire Danger Unit. 1955.

But more important, the frequency of high fire-danger days is not uniform throughout the year. In most of the Southwest high fire-danger days are much more prevalent in late spring than at other times. A fire control organization needs depth when high fire-danger days are frequent. It must have strength to stand a heavy sustained workload without losing efficiency.

Charts like figure 9 are used to identify fire seasons. Both the largest number of fires and the highest drought indexes appear in May, June, and July. When fire business in most concentrated, the strongest organization will be needed. The beginning of the regular fire season is tentatively set at the time when the drought index reaches 77 (high) and the ending when drought index drops below 77. This procedure tentatively divides the fire season into three parts.

The next step is to analyze rate-of-spread indexes within each season. Records for several years should be used (table 4).

It is evident in the early season that bad fire days are improbable. Few fires start (see fig. 9). Hence, the likelihood of a fire on a bad day is low.

In the late season, bad days can be expected now and then. In the area used as an example, two bad days can be expected during 100 days of late season. But fire occurrence is very low during the dry pa⁻ of the late season when bad days will occur (see fig. 9). Therefore the likelihood of a fire on a bad day in the late season is also low.

In contrast, an average rate of about one bad day a week was found during midseason. And about two more days per week were just below the serious category. Bad and near-bad days tend to bunch up. Furthermore, the fire occurrence rate is high. Thus, the probability of fires during serious burning conditions is high.

Table 4. --Distribution of days by drought index and rate-of-spread index
classes within "fire seasons"

Drought index class	Rate-of-spread index class	Fire season		
		Early	Mid	Late
		Probability of occurrence[1]		
Low and moderate	Low	79	10	36
	Moderate	11	1	1
	High	10	0	0
High and extreme	Low	0	50	43
	Moderate	0	27	18
	High[2]	0	12	2
	Extreme[2]	0	0	0

[1] Number of days in 100 that given combinations of indexes occurred in each subdivision of the fire season.

[2] Conditions when serious fires are both possible and probable unless fire control action is fast and strong.

The fire control organization should be adjusted to fit the season. Costly, battle-ready forces are commonly not needed during the early and late parts of the fire season. Ordinarily good detection backed up by a well distributed mobile skeleton force, which usually can be filled by workers from projects other than fire control, can handle the situation. When forecasts warn that the weather may approach or reach serious conditions, these small units can be placed on a special alert for the duration, usually no more than a burning period or two. If a fire does start it usually is possible to contain it by pulling together units from several locations. It may or may not be necessary to fill the holes created in the preparedness network depending on the specific circumstances. The chances for having to fight more than one fire at a time during these seasons are small.

On the other hand there is need during midseason for a strong battle-ready organization with adequate depth to fight several project fires at once without weakening the preparedness force at any point. Midseason is the time when the cost of strength is justified.

If the first effort does not break the fire season into subseasons with the characteristics described above, adjustments should be made in the dividing dates until the serious periods are clearly defined.

Three subdivisions of the fire season may not be needed in every fire control unit. Each unit should be analyzed independently. The number of subseasons and their limits should fit the conditions within each unit. In some units a seasonal breakdown may not be justified at all; the chance of a fire burning on a bad day may be small throughout the year.

After the fire-season analysis has been completed, the next step is to group days rated by the two index classes into operational categories. This is done by dividing the many possible combinations of the two indexes into groups for which changes in organization will be made.

There is no fixed pattern for these groupings. The categories to use should be based on an analysis of the workload within each protection unit. Furthermore, the analysis should be continuing so the categories may be changed whenever the character of fire-setting agents, type or condition of fuels, facilities for preventing and suppressing fires, and similar factors change within a unit.

Changes in prevention and suppression facilities are especially important. The number of fire-danger categories that can be used effectively in a protection unit that has no special equipment may be small. But when helicopters, aerial bombers, smokejumpers, and other special facilities become available more operational categories of fire danger may be needed to use the added facilities efficiently.

Fire control costs can be minimized if the procedures outlined here are followed faithfully. High cost facilities will be listed in the plans and employed only when high intensity fires are likely. That is only a small percentage of the total time fire plans are in effect, even in bad years. When high intensity fires are unlikely, fire control expenditures can be held at a low level.

Fire business experience is the basis for developing operational categories. It can be recorded on a work chart (fig. 10). The drought index and rate-of-spread index scales are subdivided as each case warrants to form the number of cells desired. Past indexes can be calculated from U. S. Weather Bureau records if fire-danger measurements are not available. Some types of data, such as individual severe fires, may represent a composite of several protection units if business on individual units is light.

After the work chart has been prepared and studied, cells are grouped as similar situations warrant. Operation plans are matched to the business each group represents.

A sample grouping of fire-danger indexes into operational categories is included next. A work chart must be developed for each season if this plan is followed. Note that some units require more and some less than those illustrated.

A. Early season

　　1. Drought index 1-56, rate-of-spread index 5-100
　　2. Drought index 57-76
　　　　a. Rate-of-spread index 5-35
　　　　b. Rate-of-spread index 40 or more

B.   Regular mid-season

  1.   Drought index 1-76

    a.   Rate-of-spread index 5-35

    b.   Rate-of-spread index 40 or more

  2.   Drought index 77-100

    a.   Rate-of-spread index 5-15

    b.   Rate-of-spread index 20-35

    c.   Rate-of-spread index 40 or more

C.   Late season

  1.   Drought index 1-76

    a.   Rate-of-spread index 5-15

    b.   Rate-of-spread index 20 or more

  2.   Drought index 77-100

    a.   Rate-of-spread index 5-15

    b.   Rate-of-spread index 20-35

    c.   Rate-of-spread index 40 or more

R.O.S. INDEX	DROUGHT INDEX			
	0-56	57-76	77-90	91-100
5-15	60 days (1) 0/0 104 a+b fires	204 days 3/0 (6) Delayed attack 10 a+b fires	217 days 19/2 35 a+b ROS probably higher at fires	125 days 17/4 26 a+b
20-35	0 0/0	16 days 0/0 no fires	79 days 2/0 (4) 13 a+b fires	55 d. Class C→10/1 Class D+E⁴ 18 a+b
40-65	1 day 0/0 no fires	8 days 0/0 no	22 days 0/0 Pivet Fire Big Elk Fire 2 a+b fires	36 days 15/4 Buskala Fire 4 a+b
70-100	0 0/0	0 0/0	0 0/0 (5) Circle Cross McVey	1 day 1/1 Escudillo (2) McKnight Little Creek (3) Dudley Lake Lincoln Creek Rock Creek

Figure 10.--Fire planning work chart for recording fire business experience showing in each cell: (1) number of days, (2) number of fires 10 acres and larger, (3) number of fires 100 acres and larger, (4) number of fires less than 10 acres, (5) individual severe fires, and (6) other pertinent information.

As an alternative, fire-danger indexes may be collected into a selected number of classes (fig. 11). Where extensive rather than intensive use is made of fire-danger ratings, this may be the better approach. One work chart must cover all seasons for this procedure. Note that in this approach one step is added and, generally, flexibility and refinement are reduced somewhat.

R.O.S. INDEX	DROUGHT INDEX			
	0-56	57-76	77-90	91-100
5-15	I	III	V	VI
20-35	II	III	VI	VIII
40-65	II	IV	VIII	IX
70-100	IV	VII	IX	X

Figure 11.--Fire planning work chart illustrating method of designating operational classes or categories based on fire business experience record (see fig. 10).

For each combination of indexes such as B-2-c, A-2-a, or Class X an individual action plan is written. The plan for each condition should be specific, complete, and independent. Strength of forces, positions to be occupied, and all prevention and preparedness activities should be spelled out in detail so nothing will be overlooked when the plan is put into motion. A threefold plan is recommended (figs. 12, 13, and 14). One part is procedures or activities; the second is planned pre-fire organization; and the third is the organization map. A form for less detailed planning is illustrated by figure 15.

When drought index is 77 or more and rate-of-spread index 40 or more, the location of initial attack units should be planned carefully. If a fire goes beyond 10 acres during these conditions, analyses show that the odds favor its escaping the initial attack force and going on to become serious. Fires during these conditions of high flammability generally wind up in one of two size classes: less than 10 acres, or over 100 acres. The chances of holding a fire with reinforcements at an intermediate size are poor. If the initial attack unit cannot control the fire while it is still small, it escapes and becomes a project fire.

CONDITIONS: Dry and windy. Fires ignite readily, spread rapidly, have the potential to become serious, and are difficult to control. Crowning is likely. Fires over 10 acres may whirl, spot badly, and develop other extreme characteristics. Risk of man-caused fires is high.

SPECIAL SPECIFIC PROCEDURES:

A. PREVENTION

1. Ranger enforce "smoking code" for F. S. employees.

2. Ranger contact program manager Radio Station KCOL and have script C (extreme fire danger) broadcast.

3. Ranger contact woods boss Jones Timber Company sale to see that prearranged company prevention guard will be on duty to enforce "smoking code," ban all fires and operation of power saws, and eliminate all other hazards found while currently inspecting operations.

4. Assistant ranger post "extreme fire danger" signs according to poster plan.

5. Blue patrolman inspect Jones Timber Company woods operation after quitting time, between 5:30 and 6:00 p.m., for smokes.

6. Blue patrolman visit sheep camp, Barney allotment, morning and afternoon and see that there are no open fires.

7. Blue patrolman visit campers at Big Pond and Cold Water campgrounds in afternoon; warn that fires and smoking permitted only in improved area.

B. DETECTION

1. Red patrolman check for smokes 10:00 a.m. - 7:00 p.m. from Bald Peak while enroute, about 2-hour intervals.

2. Aerial observer fly route A at 1:00 p.m. and 3:00 p.m.

C. PREPAREDNESS

1. Dispatcher fill in behind every presuppression crew dispatched before 3:00 p.m.

D. SUPPRESSION

1. Dispatcher have aerial observer scout every smoke promptly.

(NOTE: This is a check list. It can be arranged by both subject matter and by persons responsible. For the higher danger days job lists based on this plan should be ready beforehand to give to each employee.)

Figure 12. --Sample activities plan.

```
                              DROUGHT INDEX        77 - 100        Page_____
            Wilco N. F.       RATE-OF-SPREAD INDEX  40 - 100      Date made or
Unit___Jerry District___      SEASON_____Regular (mid-season)_    revised_____


TIME STANDARDS:   (Maximum allowed when these conditions exist or are predicted)

     Discovery___20___ minutes      Get-away_____5___ minutes

     Report_____5_____ minutes      Travel_____60___ minutes regular fuel

                                           _____30___ minutes slash fuel


PLANNED PRE-FIRE ORGANIZATION:


           Location                             Position

     Jerry Ranger Station            Ranger (Standby)
                                     Assistant ranger (Standby 10A-6P)
                                     Dispatcher
                                     5-man crew with equipment operator
                                         (Standby 10A-6P)

     Wright Airfield                 Aerial observer (Standby 10A-6P)

     Blue Lookout                    Lookout
                                     Blue patrolman (patrolling 9A-7P)
                                     2-man crew (Standby 10A-6P)

     Green Lookout                   Lookout
                                     2-man crew (Standby 10A-6P)

     Red Lookout                     Lookout
                                     Red patrolman (patrolling 10A-7P)
                                     1-man crew (Standby 10A-6P)

     Compartment 10                  10-man TSI crew (1 man Standby at
                                         telephone 8A-5P: workdays)

     Blackjack Community             10-man cooperative crew (1 man
                                         Standby at telephone 8A-5P:
                                         non-workdays)

(NOTE:  Second line of defense, replacements, etc., are not shown.  Only those
units with specific areas of responsibility in the pre-fire organization should be
listed here.)
```
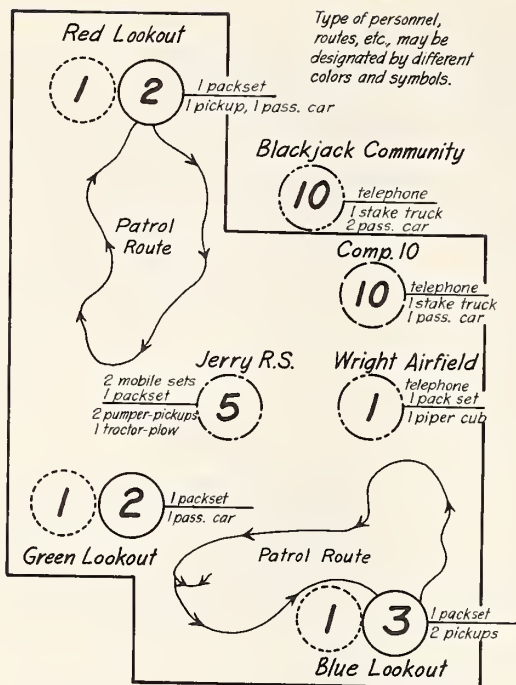
Figure 13. --Sample organization plan.

Figure 14. --Sample organization map.

Figure 15. --Sample of form for less detailed planning.

Figure 16 can be used for planning proper distribution of initial attack units. The solid line indicates the time required for fires to reach 10 acres in size. It is based on fires burning litter in moderately stocked all-aged stands on moderately sloping terrain.
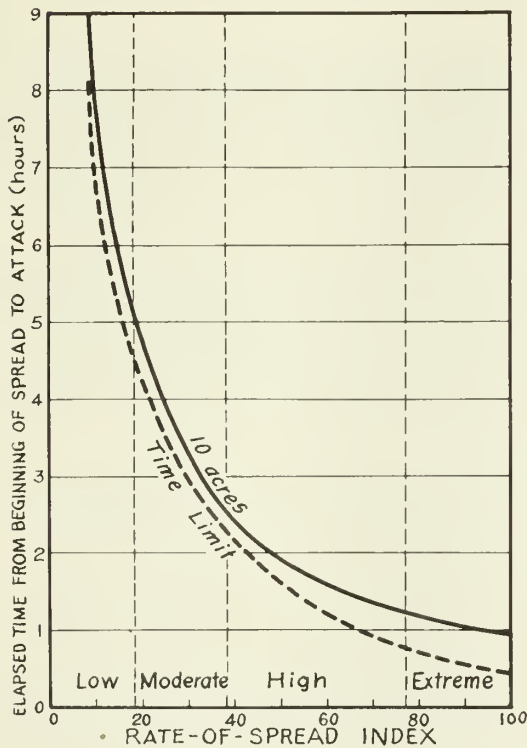

Figure 16. --The solid line indicates the time required for fires to reach a size of 10 acres when burning in litter in moderately stocked all-aged stands on moderately sloping terrain. The dashed line indicates the elapsed time within which attack must be started by an initial attack unit of sufficient strength to stop its spread before reaching 10 acres in size.

In some units or parts of units records may show that fires spread slower or faster than the graph indicates. Specific curves should be developed from local records for these situations.

The dashed line indicates the time within which suppression work must be started by an initial attack force of sufficient strength to control the fire. From 15 to 30 minutes are allowed for effectively stopping the spread of the fire before it passes the critical size of 10 acres.

When drought index is 76 or less, greater elapsed time can be allowed. Fires are easier to control and the risk of serious fires is practically nil. Time and strength of attack can then be planned to minimize costs.

Although specific details of fire prevention and presuppression plans should be designed separately for every unit, there is a common basic approach to planning and carrying out plans in all units. The principles can be illustrated by baseball strategy where defense is planned beforehand. When a long-ball hitter who is likely to hit to the far right steps into the box, the defensive team manager moves the out-fielders deeper and to the right. The team arranges to defend against the known potential of the hitter.

The fire-control manager should operate in the same way. He should size up the potential of every day by calculating drought index. And for each level of drought index his plans are made beforehand to give him the best possible defense. For example his plans may call for use of a helicopter when drought index is high or extreme and rate-of-spread index is high. When drought index alone is high, he should make sure that the helicopter (already under contract) is available, and is ready for use on short notice, should the rate-of-spread index turn high.

But like the baseball manager the fire-control manager does not make full provisions for meeting the worst possible situation on the basis of potential alone. Because the batter is a potential long-ball hitter to hard right the manager doesn't put the right fielder back against the fence on the right foul line. The manager puts the fielder in a position where he can cover that far corner if necessary. Similarly the fire-control manager does not actually put the helicopter at a specific spot on the basis of drought index alone. On the basis of fire potential he sees'that all facilities are ready and able to cover situations that may come up. If a high rate-of-spread index is predicted when drought index is already high or extreme, the fire-control manager starts the helicopter for a specific position immediately and fast. On the basis of measured fire danger, he makes adjustments as needed so he will have the proper plan in effect to handle the situation that actually develops.

In fire control the necessary adjusting is carried out in accordance with specific written plans. The high degree of flexibility needed to efficiently handle fire control work is afforded by using one index that gages potential and another index that gages the opportunity for the event to measure up to the potential. Men and facilities are made ready on the basis of the index of potential. But they are not actually deployed until the second index predicts that they are actually needed. When ready but not actually deployed facilities can usually be on call at small cost. They can be deployed to specific locations quickly when needed. Thus it is both possible and feasible to actually build up an organization capable of handling the worst possible situation without incurring all the costs.

In summary, the two indexes make it possible for alert fire control managers to handle fire control operations efficiently anytime, anywhere.

SAMPLING FIRE WEATHER

NOTE: Stations that serve the U. S. Weather Bureau or other agency are to be located, equipped, and operated in accordance with their standards and instructions. Disregard any part of the following discussion that conflicts with them.

PROCEDURES

The following instructions apply to measurements made to rate fire danger for the day. Measurements made for other purposes may be different.

Precipitation

From the time drought-index calculations stop in autumn to the time they start in spring, precipitation need not be measured daily for fire-danger rating. The total amount for the period is the only figure needed.

Rain gages may be left unattended. When gages are left unattended, place 3 to 6 inches of saturated calcium chloride solution (to prevent freezing and also to melt snow) and 2 ounces of light motor oil (to retard evaporation) in the gages at the beginning of winter and record the depth of this mixture so it will not be counted as precipitation in spring. Three inches of solution will be enough if the amount of precipitation expected is 2.5 inches or less. Six inches of solution will be needed for precipitation of 4.0 inches. Regular permanent type antifreeze solution may be substituted for the calcium chloride solution.

Do not use the regular rain gage stick to measure this liquid or any liquid in the gage so long as a trace of oil remains in the gage. Until the gage has been thoroughly washed in spring to remove the oil, a slender straight stick may be used to determine the depth of the liquid. The depth on the stick can be scaled in inches by placing the stick alongside a ruler.

Precipitation that falls in spring after drought-index calculations have started and are continuing is not counted as winter precipitation, even though it may fall as snow or ice. Mark frozen precipitation with an "S" on the record form.

When drought-index calculations start in spring, measure the total winter precipitation or add up the total for the winter period.

From the time drought-index calculations start in spring until they stop in autumn all precipitation that falls is measured and recorded daily. For fire-danger-rating purposes, the amount is recorded at 1:00 p.m. and accounts for all precipitation that fell during the preceding 24 hours. If precipitation also is reported to the U. S. Weather Bureau or other agency, take measurements at additional times to meet their requirements.

The depth of precipitation in the gage is measured to the nearest one-hundreth of an inch with a clean, regulation measuring stick. One inch on the stick equals 0.10 inch of precipitation, one-tenth inch equals 0.01 inch. The figure is recorded the same as dollars and cents, as 1.14 inches. A reading of 0.005 inch is recorded as 0.01 inch. Less than 0.005 inch is recorded as a trace (T).

Temperature

Temperature measured with a nonregistering type thermometer is read at 1:00 p.m. Temperature read from a registering type thermometer usually is read at 1:00 p.m., but may be read at a later, more convenient time when drought index is low or moderate or when rate-of-spread index is not being calculated. The latter procedure gives maximum temperature rather than temperature at 1:00 p.m. The difference is not usually large enough to be important.

When reading temperature, watch for and avoid abnormal conditions, such as momentary cloudiness during a sunny day. Temperature can fluctuate quickly and appreciably. The temperature measurement is to be truly representative of prevailing conditions.

Temperature is read to the nearest whole degree. Level the eye with the liquid in the tube or the indicator arm when taking the reading.

Wind Velocity

Measure for 2 to 4 minutes at approximately 1:00 p.m. and calculate the average in miles per hour from the sample. Measure only when the wind is blowing at a velocity representing prevailing conditions. If the wind velocity changes appreciably while a measurement is being made, discontinue the measurement and start anew when the wind velocity returns to normal.

These are the steps for measuring wind velocity with the airways-type cup anemometers attached to a buzzer or counter; (1) after throwing the switch to connect the buzzer or counter to the anemometer, listen for the first buzz or click and start timing (do not count the first contact); (2) count the contacts for exactly 2 minutes during steady winds or for exactly 4 minutes during gusty winds, and (3) divide the count by 2 if contacts were counted for 2 minutes or by 4 if contacts were counted for 4 minutes to get wind velocity in miles per hour. If a chart or table is furnished for converting contacts into miles per hour, follow the instructions furnished. Disconnect the buzzer or counter from the anemometer at all times when not in use.

Portable anemometers usually read directly in miles per hour. Velocity is indicated by a pointer, ball, disc, or similar device. Watch the indicator for at least 2 and preferably 4 minutes. Usually the indicator will "flutter" over a narrow range most of the time with occasional strong pulses. For example, the indicator may "flutter" between 15 and 17 m.p.h. with pulses every 15 - 20 seconds up to 22 m.p.h. The figure at the top of the "flutter" is an acceptable average of sustained velocity.

Readings from portable anemometers usually must be corrected for height. Ordinarily measurements are made at eye level, between 5.0 and 6.0 feet, whereas the standard for fire-danger-rating purposes is wind velocity at 20.0 feet above the ground. Velocity at 20.0 feet normally is about 1.2 to 1.5 times greater than at 5.0 to 6.0 feet. Suggested factors by which to multiply measured velocity are:

Measured wind velocity (M.P.H.)	Multiply by Factor
0 - 8	1.5
9 - 12	1.3
13 +	1.2

It is wise to check each type of portable anemometer against a regular 20-foot high standard anemometer to find a true correction factor. If it deviates appreciably from the above values, correct the table to fit the individual type of instrument.

These procedures may appear imprecise. For fire-danger rating, the aim is to get measurements that represent sustained velocity during early afternoon, that are consistent from day to day, and that are consistent from place to place. If these objectives are met, it is possible to gage differences in fire danger from one time to another and from one place to another, and satisfy the general objectives of fire-danger rating. Guides in this section help get the type of measurements needed. But the observer should constantly keep the target in mind--representative, consistent, comparable measurements. He should avoid momentary lulls, gusts, and other abnormal or temporary conditions. He should see that the anemometer functions properly. He should apply a suitable correction factor when needed. A great deal depends upon the judgment and training of the observer.

LOCATION OF INSTRUMENTS

Fire-danger measurements should be made in openings within the ponderosa pine type. The ideal is a grassy park 2 to 10 acres in size on a broad mesa, in a broad valley, or in gently rolling topography. Other sites are less desirable, but sometimes must be accepted. The objective is to get free movement of air around the instruments. Avoid local obstructions.

Measurements do not necessarily have to be made at stations or fixed locations. The objective is to sample weather within the boundaries of a fire-danger-rating unit. Sampling may be done at different locations from time to time, provided the sampling is done uniformly. Portable anemometers and thermometers may be used, but exposure standards should be followed rigidly.

These are the standards for exposing the instruments:

Precipitation Gage

Install so the gage will be away from trees, buildings and other obstructions a distance equal to at least two times, and preferably four times the average profile height of the obstruction. Where there is little or no snowfall, mount the gage with the top 36 inches above the ground or 36 inches above the average crown profile of weeds, etc., if the herbage is of appreciable height. Where there is heavy snowfall, mount the gage on a support above the highest level of the snowpack.

Maintain the top of the gage level.

Shelter and Thermometer

Install in a reasonably level spot away from trees, buildings, and other obstructions a distance equal to at least two times, and preferably four times the average profile height of the obstruction, and at least 100 feet from any extensive areas of pavement or irrigation.

Install the shelter so the thermometer can be placed at about eye level of the observer.

If a portable thermometer is used no shelter is needed; nevertheless the thermometer should be shielded from direct sunlight and intense

reflected radiation from the ground or from highly reflective objects. Normally this can be done by shading briefly with a hat, notebook, or similar object that is not highly reflective.

Anemometer

Install the nonportable type in relatively level topography. Adjust the height of the instrument according to the following table:

Table 5. --Factors for correcting anemometer height
to compensate for obstructions[1]

Anemometer distance from obstruction[2]	Correction for obstruction	Total height of anemometer above ground[3]
Feet	Feet	Feet
0	h	[4] $h + z + 20$
h	0.70 h	0.70 $h + z + 20$
2h	.50 h	.50 $h + z + 20$
3h	.35 h	.35 $h + z + 20$
4h	.20 h	.20 $h + z + 20$
5h	.10 h	.10 $h + z + 20$
6h	.05 h	.05 $h + z + 20$
7h	0 h	$z + 20$

[1] Adopted from Fons, W. L., and Buck, C. D. Fire danger rating standards. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. 1944. [Unpublished.]

[2] If it is impossible to place the anemometer at a distance from an obstruction, place it above the obstruction.

[3] Total height includes the 20 feet minimum, plus obstruction and surface corrections.

[4] h = height of the obstruction. For buildings, use the height of the ridge; for timber stands use the average height of the crown profile
z = average height of the ground cover.

Maintain the spindle of the anemometer perpendicular at all times. Arrange for easy servicing of the instrument.

With portable-type anemometers measure wind at similar locations. Since wind direction will be known when these measurements are made, completely avoid obstructions.

TYPES OF INSTRUMENTS

There are many good types of instruments that may be used. However, it is wise for any agency to standardize to facilitate purchase and maintenance.

Rain Gage

The Forest Service type is satisfactory. It is made of galvanized iron or aluminum, is about 12 inches high, and slightly less than 8 inches in diameter. The capacity is 1/2 inch in the measuring tube plus 6 inches overflow in the large can.

The copper and bronze U. S. Weather Bureau type is excellent but costly.

Thermometer

The maximum-minimum registering type is recommended for permanent installations; the nonregistering type, for portable use.

There are two general types available: (1) liquid-in-glass and (2) bimetallic. The bimetallic type is preferred. The usual type has a dial and three hands: one shows maximum, one shows minimum, and the third shows current temperature. It is compact and easy to shelter.

Shelter

The purpose of the shelter is to protect the thermometer from injury, shield it from radiation, and allow free circulation of ambient air representative of a forested site. Any structure that will do that is acceptable.

The usual "cotton region" or louvered-type shelter is not recommended, although acceptable. It is expensive.

The "coolie hat" type aluminum shelter, such as shown in figure 17, is a good design for bimetallic registering thermometers. It is well ventilated, provides an effective radiation shield, has small mass, and is inexpensive.

Each agency should work out an efficient design that meets its needs.

One special note: If the shelter is wooden, it should be painted white on the outside to reflect radiation; if metal, the outer surface should either be highly reflective or painted white. Shelters with dark-colored exteriors should be avoided.

Anemometer

The standard "airways" type with 1/60 mile contact is recommended for permanent installations. There are several satisfactory brands.

When selecting a brand, consider (1) design of the instrument, (2) ability of supplier to promptly fill orders for new instruments, service, or repair parts, and (3) cost.

A very important feature of design is the mechanism for making the electrical contacts. An instrument may have only one breaker point or several. An instrument with only one breaker point has a distinct practical

advantage; it either makes contact every time it should or it does not make contact at all. On the other hand, an instrument with five breaker points, for instance, may make contact with four points and miss one without the observer knowing.

Figure 17. --"Coolie hat" type shelter for maximum-minimum registering thermometer. Diameter of the base of the cone is 14 inches. Diameter of the flat-plate radiation shield is 12 inches. Distance from base of cone to shield is 4 inches. Cone and shield are made of aluminum. Outer surfaces are polished. Inside of cone and top of shield are painted dull black.

MAINTAINING, INSPECTING, AND TESTING INSTRUMENTS

Regular maintenance is limited to cup-type anemometers. Standard: monthly during windy, dusty periods; bimonthly otherwise. Disassemble, wash in solvent, oil moving parts lightly, and reassemble. Use very light oil, like typewriter oil, sparingly. Heavy oil may gum up the instrument and too much oil may interfere with the contact mechanism.

A responsible officer other than the observer should inspect all fire-danger measuring instruments at least annually. A good time for an inspection is just before the regular (or mid) fire season. See that instruments are exposed correctly and functioning properly. Check functioning of instruments against a calibrated anemometer and thermometer carried by the inspector.